DOE/ET/27145--2

COMPUTER SIMULATION OF NONCONDENSIBLE
GAS BEHAVIOR IN GEOTHERMAL POWER
PLANTS UTILIZING DIRECT CONTACT HEAT
EXCHANGE

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MASTER

REPORT OF WORK

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Department of Energy

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ABSTRACT

During FY 1979 a computer model was developed to simulate the behavior of carbon dioxide and hydrogen sulfide in a geothermal power plant using direct contact heat exchange with isobutane as a working fluid. This computer program was modified to simulate the particular equipment characteristics of the 500 kw direct contact pilot plant at East Mesa. Vapor and liquid compositions and temperatures can be calculated throughout the heat exchangers in the pilot plant. The program is now available for analysis of the pilot plant operation and for design of similar plants.

INTRODUCTION

In the direct contact heat exchange concept for geothermal power production, an immiscible working fluid is mixed with the geothermal brine and extracts heat from it. The working fluid comes from the condenser as a cold liquid and by direct contact heat exchange is heated to its boiling point and then vaporized. The vapor stream from the direct contact heat exchanger (DCHX) passes through a turbine (which turns the generator) and then into the condenser, where it is liquified and cooled.

The purpose of this project was to simulate the particular equipment characteristics of the 500 kw pilot plant at East Mesa. In the pilot plant preheating and boiling of the working fluid are carried out in a single vessel, which is 42 inches in diameter and 38 feet high. The condenser is made up of 1-inch diameter horizontal tubing, each tube 180 feet long and folded into 10 passes. There are four units each containing 96 tubes. The vapor from the turbine condenses inside the tubing. An air-water mixture is blown over the outer surfaces of the tubes.

The hot brine entering the DCHX contains dissolved carbon dioxide, with observed concentrations as high as ~ 1000 ppm. Other noncondensable gases, such as hydrogen sulfide, are not present in significant concentrations. In the field tests the carbon dioxide content of the hot brine entering the DCHX was varied down to concentrations around 300 ppm by preflashing to different pressures.

Backmix Boiler Model

The boiler and preheater are a single vessel, the boiler being the topmost portion. The hot brine enters from the top of the DCHX and is sprayed out radially below the liquid level. The effect is to produce a highly-turbulent, well-mixed zone for boiling which is thought to be fairly shallow (~ 2 ft deep).

The boiler was modeled as a well-mixed tank with continuous feed and effluent streams. The brine phase is assumed to exist throughout the boiler at the temperature and composition of the effluent stream, which descends to the preheater. Two mass transfer processes are of concern in the boiler: (1) the dissolution of isobutane into the brine, and (2) stripping of carbon dioxide from the brine into the vapor phase.

The rate of mass transfer to the brine phase can be written in terms of a material balance or in terms of a mass transfer coefficient. The material balance relationship is:

$$R = B (X_o - X_1) \quad (1)$$

The rate in terms of the mass transfer coefficient is

$$R = (k_x a) V (X^* - X_1) \quad (2)$$

Equations (1) and (2) may be combined by eliminating R , and solving for X_1

$$X_1 = \frac{(k_x a) (V)(X^*) + (B) (X_o)}{(k_x a) (V) + B} \quad (3)$$

For the case of isobutane dissolution into the brine, X_o is 0.

Equation 3 is valid whether the net transfer is into the brine phase (as for isobutane dissolution) or out of the brine (as for noncondensable gases). For the noncondensable gases, X^* depends on the composition of the vapor phase.

A material balance equation for the vapor phase analogous to equation 1 is:

$$R = B_1 (Y - X_{10}) \quad (4)$$

Implicit in equation 4 is the assumption that the molar flow rate of vapor is equal to that of the isobutane.

The equilibrium solubility in the brine is obtained through the Henry's constant:

$$H = P_t Y / X^* \quad (5)$$

Equations 1, 4 and 5 are combined to eliminate R and Y and solved for X^* :

$$X^* = \frac{P_t}{H} \left[\frac{B}{B_1} (X_o - X_1) + X_{10} \right] \quad (6)$$

Equations 3 and 6 may be combined to eliminate X^* and yield X_1 :

$$X_1 = \frac{(k_x a) (V) (P_t / H) \left(\frac{B X_o}{B_1} + X_{10} \right) + (B) (X_o)}{(k_x a) (V) + B + (k_x a) (V) (B / B_1) (P_t / H)} \quad (7)$$

Mass transfer coefficients for the boiler were calculated from the heat transfer coefficient through the j - factor analogy. This approximation was necessary because experimental measurements of mass transfer coefficients in direct contact boilers have not been made. Thus, from

the Colburn (or j-factor) analogy between heat and mass transfer

$$k_x a = \frac{1}{C_p M} \cdot \left[\frac{N_{Pr}}{N_{Sc}} \right]^{2/3} U_v \quad (8)$$

A well-accepted general correlation for predicting values of U_v is not yet available. Values obtained for the isobutane-water system by DSS at Wrightsville Beach ranged from 7900 to 16,900 Btu/hr - ft³ - °F. Their data were correlated by the equation

$$U_v = 6500 \left[P_c / P_{SAT} \right]^{0.56} \quad (9)$$

Values for U_v for the isobutane-water boiler at East Mesa are reported by Lawrence Berkeley Laboratory to be in the 30,000 to 40,000 range. Equation 9 yields a value of 7270 for the saturation temperature of 250°F at East Mesa. Therefore, the program uses an equation of the form of equation 9 but multiplies the value by a factor of 5, to produce values of U_v in the middle of the LBL range.

Preheater Model

The preheater for the 500 kw plant is a spray tower, which was modeled in the program previously developed for a generic direct contact power cycle (Knight and Perona, 1980). Briefly, the temperature profiles of the two liquid phases are calculated by the Letan-Kehat method. The tower is then divided into axial increments, for which average temperatures can be used for the evaluation of transport properties and equilibrium solubilities.

A reprint of a paper on the spray tower model presented at the 20th National Heat Transfer Conference is included as Appendix A of this report.

Condenser Model

Condensation of the vapor from the turbine takes place inside horizontal tubing with an outside diameter of 1.05 inch and a 70 mil wall thickness. The tubing is galvanized carbon steel. The condenser consists of four parallel units, each containing 96 tubes 180 feet in length. A mixture of air and water is blown over the outer surfaces of the condenser tubes. The design value of the wet-bulb temperature is 64°F with a 3.6°F temperature rise during passage.

The condenser model is based on the design method of Price and Bell (1974). This method makes two major assumptions: a) the compositions of the gas and liquid phases at the interface are the equilibrium compositions at the interfacial temperature, and b) the vapor phase resistance to heat and mass transfer is calculated using the film theory. Another assumption, utilized by Schrodtt. (2) and verified by several experimenters, is that no concentration gradient exists in the liquid film in the direction of diffusive transport (i.e. no liquid phase resistance to diffusion).

The vapor stream entering the condenser is assumed to consist of only two components - isobutane and carbon dioxide. Thus hydrogen sulfide, methane and ammonia, which are usually found to be of the order to one percent or less of the carbon dioxide concentration, are taken to be zero. Similarly, the water vapor, which amounts to one or two percent of the flow is assumed to have negligible effect on the condensation process.

The calculational steps in the model follow:

1. An incremental tube length of 6 feet is chosen. Since each tube is 180 feet long, the calculations will be carried out in 30 increments in the direction of flow:

2. Input data for an increment are:

CO₂ gas flow rate, moles/hr (V_1)

isobutane vapor flow rate, moles/hr (V_2)

condensate flow rate, moles/hr (L)

total pressure, psia (P_T)

tube wall temperature, °F (T_W)

Thermal resistance of tube wall, $\frac{\text{hr ft}^2 \text{°F}}{\text{Btu}} \left(\frac{\Delta r}{k_w} \right)$

tube fouling coefficient, Btu/hr ft²°F (h_f)

vapor temperature, °F (T_G)

3. Solve for partial pressures of carbon dioxide (P_1) and isobutane (P_2) in bulk gas flow

$$P_1 = \left(\frac{V_1}{V_1 + V_2} \right) P_T \quad (10)$$

$$P_2 = P_T - P_1$$

4. Assume temperature of the gas-liquid interface (T_i) for the increment of the tube length.

5. Obtain Henry's law constants for carbon dioxide (H_1) and isobutane (H_2) at T_i .

6. Solve for condensate composition, mole fraction carbon dioxide in condensate (X_1) and mole fraction isobutane in condensate (X_2) in terms of equilibrium partial pressures (P_{11}) and (P_{12})

$$P_{i1} + P_{i2} = P_T$$

and $P_{i1} = H_1 X_1$

$$P_{i2} = H_2 X_2$$

therefore

$$X_1 H_1 + (1 - X_1) H_2 = P_T \quad (11)$$

7. Calculate the vapor phase heat transfer coefficient (h_G) using the correlation by Chilton and Colburn (1934).

$$h_G = j_H G C_P N_{Pr}^{-2/3} \quad (12)$$

with

$$j_H = 0.023 N_{Re}^{-0.2}$$

8. Obtain the vapor phase mass transfer coefficient for carbon dioxide (k_{G1}) from the Colburn analogy

$$k_{G1} = j_m (G/\bar{M}) N_{Sc}^{-2/3} \quad (13)$$

with

$$j_m = j_H$$

9. The mass flux of isobutane is now calculated from the heat balance

$$h_o (T_i - T_w) = h_G \frac{E}{1-E} (T_G - T_i) + N_1 \lambda_1 + N_2 \lambda_2 \quad (14)$$

The sensible heat transferred by the diffusing vapor is expressed through the Ackermann factor, E

$$E = (N_1 C_P + N_2 C_{P2}) / h_G$$

The mass flux of carbon dioxide is

$$N_1 = k_{G1} (P_1 - P_{i1}) \quad (15)$$

10. Calculate a heat transfer coefficient for the liquid film (h_L). Near the entrance of the tube, where the vapor velocity is large, the correlation of Cavallini and Zecchin (1971) for high vapor velocities is used.

$$N_{Nu} = 0.05 (\overline{N_{Re}})^{0.8} (N_{Pr})_L^{0.33} \quad (16)$$

with

$$(\overline{N_{Re}}) = (N_{Re})_v \left(\frac{\mu_v}{\mu_L} \right) \left(\frac{\rho_L}{\rho_v} \right)^{0.5} + (N_{Re})_L$$

When the vapor Reynolds number drops below 35,000, the correlation of Chato (1962) is used:

$$h_L = 0.555 \left[\frac{g(\rho_L - \rho_v) \cdot k_L^3 h}{\mu_L \Delta T d} \right]^{1/4} \quad (17)$$

11. Calculate the total heat transfer resistance between the gas-liquid interface and the wall

$$\frac{1}{h_o} = \frac{1}{h_L} + \frac{\Delta r}{k_w} + \frac{1}{h_f} \quad (18)$$

where

Δr = tube wall thickness

k_w = thermal conductivity of wall

h_f = fouling factor

12. Calculate the interface temperature. This is obtained by equating

$$h_o (T_1 - T_w) = h_G \frac{E}{1 - e^{-E}} (T_G - T_1) + k_{G1} \lambda_1 (P_{G1} - P_{i1}) + k_{G2} \lambda_2 (P_{G2} - P_{i2})$$

solving for T_i

$$T_i = \frac{h_G \left(\frac{E}{1 - e^{-E}} \right) T_G + \sum_j k_{Gj} \lambda_j (P_{Gj} - P_{ij}) + h_o t_w}{h_o + h_G \left(\frac{E}{1 - e^{-E}} \right)} \quad (19)$$

13. Compare calculated and assumed values of T_i . If significantly different, repeat steps 4 through 12.
14. Calculate values for V_1 , V_2 , L , and T_G for the next increment.

The computer program carries out this sequence of calculations for each of the 30 increments. For the 500 kw plant T_i is close to 89°F for the first increment. For subsequent increments, the first guess for T_i is the value from the previous increment. Five cycles of steps 4 through 12 using direct iteration achieves convergence on T_i to within 0.1 °F.

RESULTS

Experimental data provided by Barber-Nichols Engineering Company included a series of runs in which the carbon dioxide content of the inlet brine was varied from about 300 ppm to about 800 ppm by varying the pressure drop taken on the preflash step. For these runs the carbon dioxide content of the vapor varied in a roughly linear fashion, as shown in Figure 1.

When the computer simulation of the 500 kw plant was carried out using a U_v value of 36,000 Btu/hr ft³ °F, the calculated values for the boiler exit vapor carbon dioxide content were high by a factor of about 1.5. The difficulty was traced to the computer estimation of the Henry's law constant for carbon dioxide in isobutane.

Henry's law constants for carbon dioxide in isobutane were measured by Besserer and Robinson at 250°F, which is the boiler saturation temperature. However, their data covered a pressure range which is above the boiler pressure. Henry's constants from their data range from 70.1 atm at 701 psia to 87.3 at 524 psia, their lowest pressure. The boiler program calculates a value of 86 atm, which is probably much too low for the boiler pressure of 450 to 460 psia. The API technical data book indicates a value of around 150 atm for carbon dioxide in normal butane at the boiler temperature and pressure.

The effects of increasing the Henry's constant by factors of 1.3 and 1.5 are shown in Table 1. A factor of 1.5 brings the program results into good agreement with the experimental results for the carbon dioxide concentration in the boiler vapor, as shown by the calculated points in Figure 1.

Figure 1. Comparison of Experimental and Calculated CO₂ Content of Boiler Exit Vapor.

Unexpected temperature profiles have been observed in the preheater for the pilot plant at East Mesa. There has been some speculation that these temperature plateaus have been caused by gas evolution in the preheater, causing axial mixing. As an illustration of the usefulness of the computer simulation program, equilibrium partial pressures for each component in each phase were calculated along the length of the preheater. If the total pressure of 450 to 460 psia were exceeded, then gas evolution would be expected.

The results are shown in Table 2. The sum of the equilibrium partial pressures does exceed the total pressure for about the top seven increments. Thus gas evolution in the preheater would be expected.

A Fortran listing of the simulation program and results for a sample case are shown in Appendix B. Note that the carbon dioxide content in the preheater brine rises steadily as the brine flows to the bottom. The carbon dioxide content of the exit brine from the preheater equals that of the inlet brine to the boiler. A slight convergence error (0.000341 vs 0.000350) is shown in the example case.

Mass transfer calculations in the preheater were done using concentration units of "moles/cu. ft." These were then converted to "mole fraction" units in the output subprogram. Because the density of the liquid isobutane changes severely in the preheater, from 23.1 lb/cu. ft at the top to 32.7 at the bottom, the "CO₂ in iso" numbers in the preheater output look as though the CO₂ mass balance is being violated in the preheater. This is not the case, and the mass balances are sound.

Table 1
EFFECTS OF ADJUSTING HENRY'S LAW CONSTANT
FOR CARBON DIOXIDE IN ISOBUTANE

<u>Factor</u>	<u>CO₂ in Boiler Vapor, Mole Fraction</u>	<u>CO₂ in Boiler Brine Effluent, Mole Fraction</u>
1	0.0083	0.000033
1.3	0.0065	0.000024
1.5	0.0057	0.000020

TABLE 2

EQUILIBRIUM PRESSURES IN PREHEATER

CO ₂ in <u>BRINE</u>	CO ₂ in <u>ISO</u>	<u>V.P. ISO</u>	<u>V. P. BRINE</u>	<u>TOTAL</u> <u>PRESSURE</u>
0.3090+01	0.3690+01	0.4370+03	0.3130+02	0.4750+03
0.4640+01	0.4640+01	0.4330+03	0.3080+02	0.4730+03
0.6570+01	0.6570+01	0.4290+03	0.3030+02	0.4720+03
0.7920+01	0.7930+01	0.4240+03	0.2980+02	0.4700+03
0.8900+01	0.8910+01	0.4190+03	0.2920+02	0.4660+03
0.9620+01	0.9630+01	0.4130+03	0.2850+02	0.4610+03
0.1020+02	0.1020+02	0.4070+03	0.2780+02	0.4560+03
0.1060+02	0.1060+02	0.4010+03	0.2700+02	0.4490+03
0.1090+02	0.1090+02	0.3940+03	0.2620+02	0.4420+03
0.1110+02	0.1110+02	0.3860+03	0.2530+02	0.4340+03
0.1130+02	0.1130+02	0.3780+03	0.2440+02	0.4250+03
0.1140+02	0.1150+02	0.3690+03	0.2340+02	0.4150+03
0.1160+02	0.1160+02	0.3600+03	0.2240+02	0.4050+03
0.1170+02	0.1170+02	0.3490+03	0.2130+02	0.3940+03
:	:	:	:	:
0.1150+02	0.1170+02	0.2410+03	0.1100+02	0.2760+03
0.1140+02	0.1160+02	0.2250+03	0.9680+01	0.2580+03
0.1120+02	0.1140+02	0.2080+03	0.8390+01	0.2390+03
0.1100+02	0.1120+02	0.1910+03	0.7160+01	0.2210+03
0.1070+02	0.1090+02	0.1740+03	0.6000+01	0.2020+03
0.1040+02	0.1070+02	0.1570+03	0.4920+01	0.1830+03
0.9930+01	0.1020+02	0.1400+03	0.3930+01	0.1640+03
0.9450+01	0.9790+01	0.1240+03	0.3060+01	0.1460+03
0.6860+01	0.9230+01	0.1090+03	0.2290+01	0.1290+03

NOMENCLATURE

B	=	flow rate of brine, moles/hr
B_i	=	flow rate of isobutane, moles/hr
C_p	=	heat capacity
d	=	tube diameter
E	=	Ackermann factor
G	=	mass velocity of vapor, lb/hr ft ²
h	=	$\lambda + (3/8) C_p (T_i - T_w)$
h_G	=	vapor heat transfer coefficient
h_o	=	condensate heat transfer coefficient
K_x^a	=	mass transfer coefficient, moles/hr. ft ³
k_L	=	thermal conductivity of liquid film
$\bar{M}$	=	average molecular weight of phase
N_{Pr}	=	Prandtl number
N_{Sc}	=	Schmidt number
N_{Re}	=	Reynolds number
N_1	=	molar flux of carbon dioxide
N_2	=	molar flux of isobutane
N_{Nu}	=	Nusselt number, $h_L d/k_L$
$(N_{Re})_v$	=	Reynolds number for vapor based on superficial vapor velocity
$(N_{Re})_L$	=	Reynolds number for liquid based on superficial liquid velocity
P_t	=	total pressure
R	=	rate, moles transferred/hr
T_G	=	vapor temperature
T_i	=	vapor-liquid interface temperature
T_w	=	wall temperature

- U_v = volumetric heat transfer coefficient
- V = volume of boiler, ft^3
- X^* = equilibrium solubility in brine, mole fraction
- X_o = concentration in brine entering boiler, mole fraction
- X_1 = concentration in brine leaving boiler, mole fraction
- X_{io} = concentration of noncondensable species in isobutane entering boiler, mole fraction
- Y = concentration of noncondensable species in exit vapor, mole fraction
- λ = latent heat of vaporization
- ΔT = $T_1 - T_w$

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APPENDIX A

Reprint of paper

"A Mass Transfer Model of A Spray Tower Direct
Contact Heat Exchanger"

J. F. Knight and J. J. Perona

to be presented at the

ASME-AIChE 20th National Heat Transfer Conference

Milwaukee, Wisconsin

August 2-5, 1981

PROGRAMS: AUTOCBL(CBLPAC)

EFFECT: NAME(MAIN) OPTIMIZE(3) LINECOUNT(59) SIZE(MAX) AUTOCBL(CBLPAC)
SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT COSTMT NOXREF NCALC NOANSF TE

C- PHYSICAL PROPERTY SUBROUTINE

SUBROUTINE PROP(TFC, TBC, TOTALP)

COMMON RHC, NB, RHOF, SIGMAF, VPIC4, FIC4, MOLCO2,

1 HG, HH2S, HCC2, VPH2O, DAIC4, DACO2, DAH2S, PPCO2, CC2ATM,

1 PRCO2, TRCO2, H2SATM,

1 FRH2S, TRH2S, IC4BOT, CC2BOT, H2SBOT,

1 HH2SC4, HGO2C4, DCO2, DH2S, VISIC4,

1 BEQH2S, BEQC2, TH2SA, TCO2A, TCO2B, TH2SB

COMMON T(100), WPB, HCO2B(100), HH2SE(100), XCO2B0, XF2SE0, NBOIL

COMMON TBOIL(100), XISO(100), XCC2B(100), XH2SB(100), YCO2(100), YH2S

1(100), XCC2I(100), XH2SI(100)

COMMON TBLN, FLBR, FLIC4

COMMON PRBOIL, TSAT, KBOIL, YCO2BX, YH2SBX, XIBMX, XCC2BX, XH2SBX

COMMON TBOIA, TELGTH, RPD, TCOND, PRCOND, YCO2C(100), YH2SC(100),

1 XCO2C(100), XH2SC(100), CCNDL(100), NCCND, GCOND(100)

COMMON NVERT, NHORIZ

COMMON V1(30), V2(30), P1(30), P2(30), TVAP(30), T1(31), X1(30)

COMMON X2(30), P11(30), P12(30), FL(30), FLCC2(30)

REAL NB, MGLCC2

C BRINE DENSITY

RHOB=62.4+.46*WPB-.00265*((TBC-100.)*1.4166)

C BRINE VISCOSITY

NB=.4131*EXP(.29385*EXP(TBC/100.)*6.0971)*WPB**(.18-

1 .0076*(TBC-100.))+.6818-(.0115*((TBC-100.)*.7881))

C IC4 DENSITY

RHOF=33.4-.003676*((TFC-100.)*1.5835)

C SURFACE TENSION IC4

SIGMAF=63.35+(.375*WPB)-(1.035*TEC)+(1.05*TFC)

C VAPOR PRESSURE IC4

VPIC4=26.356*EXP(.0112*TFC)

C HENRY'S LAW IC4

HIC4=EXP(-.61425+1000.*(7.0325/((TBC-32.)/1.8+273.))

1 +15.546*ALOG((TEC-32.)/1.8+273.)/1000.)*WPB*(.09562+1000.*

1 (.055289/((TBC-32.)/1.8+273.))+.29564*ALOG((TEC-32.)/

1 /1.8+273.)/1000.))

MOLCC2=WPB*.17094

C ESTIMATE HENRY'S LAW CONSTANT FOR H2S IN BRINE

C PICK HENRY'S LAW CONSTANT ACCORDING TO TEMP.

IF(TBC.LE.212.)HG=11.6*((TBC-32.)/1.8)+420.

IF(TBC.GT.212.)HG=5.6*((TBC-32.)/1.8)+1020.

C CORRECT HENRY'S LAW FOR NAOL EFFECT

HH2S=10.4*(.1*MOLCC2)*HG

C HENRY CONSTANT CO2 IN BRINE

IF(MOLCO2.GT.2.)HCC2=62.*((TBC-32.)/1.8)+1300

IF(MOLCO2.LT.2..AND.MOLCO2.GT.1.)HCC2=51.*((TBC-32.)/1.8)

1 +1000.

IF(MOLCO2.LT..5)HCC2=42.*((TBC-32.)/1.8)+800.

IF(MOLCO2.LT.1..AND.MOLCO2.GT..5)HCC2=46.*((TBC-32.)/1.8)

1 +500.

C VAPOR PRESSURE H2O

VPH2O=10.4*(.0251*((TBC-80.)*.83)-.2951)

C DIFFUSIVITY IC4, H2S, CO2 IN BRINE

1.0 (01 JUN 79)

PROP

SYSTEM/370 FORTRAN H EXTENDED (ENHANCED)

DATE 81.056/

DAIC4=((7.4E-8*((18.02*2.6)**.5)*((TBC-32.)/1.8+273.)/
1 ((196.2**5.6)*NB))*((3.875)))

DAG02=((6.577E-8*((TBC-32.)/1.8+273.)/NB)*3.875

DAH2S=((5.403E-8*((TBC-32.)/1.8+273.)/NB)*3.875

VISIC4=.115-1.25E-3*((TFC-32.)/1.8-50.)

C DIFFUSIVITY FGR H2S, CO2 IN IC4

DCO2=7.4E-8*0.919*((TFC-32.)/1.8+273.)/VISIC4

DH2S=DCC2

C HENRY CONSTANT H2S IN IC4

IF(TFC.GT.160.)HH2SC4=.217*TFC+6.333

IF(TFC.LE.160.)HH2SC4=.35*TFC-15.

C HENRY CONSTANT CO2 IN IC4

IF(TFC.LT.120.)HCO2C4=.6*TFC+14.

IF(TFC.GE.120.)HCO2C4=.3*TFC+50.

IF(TFC.GE.140.)HCO2C4=.2*TFC+64.

IF(TFC.GE.160.)HCO2C4=.1*TFC+80.

IF(TFC.GE.180.)HCO2C4=98.

IF(TFC.GE.200.)HCO2C4=118.-0.1*TFC

HCC2=HCC2*18./RHC8

HH2S=HH2S*18./RHQB

HH2SC4=HH2SC4*58./RHQB

HCO2C4=HCO2C4*58./RHCB

HCO2C4=HCO2C4*1.5

RETURN

END

/ PROP / SIZE OF PROGRAM 0008D4 HE)

TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME		
CD	R*8	NR	FL	CD	R*8	NR	HG SF	CD	R*8	00003			
CD	R*8	NR	P2	CD	R*8	NR	T1	CD	R*8	NR			
CD	R*8	NR	X1	CD	R*8	NR	X2	CD	R*8	NR			
CD	R*8	NR	P12	CD	R*8	NR	RPD	CD	R*8	NR			
FA	D	R*8	000380	WPB	FA	CD	R*8	000438	DLCG	FA	XFD*	R*8	00000
S	CD	R*8	000008	FLBR	CD	R*8	NR	FCC2	SF	CC	R*8	00004	
S	CD	R*8	000028	PROP	D	R*8	000388	RHOB	SF	CD	R*8	00000	
CD	R*8	NR	TSAT	CD	R*8	NR	TVAF	CC	R*8	NR			
CD	R*8	NR	YH2S	CD	R*8	NR	CONDL	CD	R*8	NR			
S	CD	R*8	000068	DAIC4	S	CD	R*8	000058	FLCC2	CC	R*8	NR	
CD	R*8	NR	HCC2B	CD	R*8	NR	FF2SB	CC	R*8	NR			
CP	I*4	NR	NCONB	CP	I*4	NR	NVERT	CP	I*4	NR			
CD	R*8	NR	FRH2S	CD	R*8	NR	TEDIA	CD	R*8	NR			
CD	R*8	NR	TCO2A	CD	R*8	NR	TCO2B	CD	R*8	NR			
CD	R*8	NR	TRCO2	CD	R*8	NR	TRH2S	CD	R*8	NR			
S	CD	R*8	000020	XCO2B	CD	R*8	NR	XCC2C	CD	R*8	NR		
CD	R*8	NR	XH2SC	CD	R*8	NR	XH2SI	CC	R*8	NR			
CD	R*8	NR	YH2SC	CD	R*8	NR	FOXPD#	XF	R*8	00000			
CD	R*8	NR	CO2ATM	CD	R*8	NR	CO2BCT	CD	R*8	NR			
SF	CD	R*8	000000	H2SATM	CD	R*8	NR	F2SBOT	CD	R*8	NR		
SF	CD	R*8	000030	NHOR12	CP	I*4	NR	FRBCIL	CC	R*8	NR		
S	CD	R*8	000018	TBLGTH	CD	R*8	NR	TCTALP	C	R*8	00039		
CD	R*8	NR	XCO2B0	CD	R*8	NR	YH2SBX	CD	R*8	NR			
CD	R*8	NR	YH2SBX	CD	R*8	NR							

***** COMMON INFORMATION *****

NS: AUTCCBL(DBLPAD)

EFFECT: NAME(MAIN) OPTIMIZE(3) LINECOUNT(59) SIZE(MAX) AUTCCBL(DBLPAD)
SOURCE EBCDIC NOLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NCALC NOANSF TEI

SUBROUTINE GAS

C SUBROUTINE GAS CALCULATES HENRY'S CONSTANTS FOR CO₂ AND H₂S IN BRINE

COMMON RHCB,NB,RHOF,SIGMAF,VPIC4,HIC4,MOLCO2,FG,HP2S,PCO2,

1 VPH2O,DAIC4,DACO2,DAH2S,PPCO2,CO2ATH,PRCO2,TRCC2,H2SATM,

1 PRH2S,TRH2S,IC4BGT,CO2BGT,H2SBGT,

1 HH2SC4,HCG2C4,DCO2,DH2S,VISIC4,

1 BEGH2S,BEQCO2,T12SA,TCO2A,TCO2B,TH2SB

COMMON T1(100),WPB,HCG2B(100),HH2SE(100),XCO2B0,XH2SB0,NBOIL

COMMON TBOIL(100),XISO(100),XCO2B(100),XH2SB(100),YCC2(100),YH2S

1(100),XCC2(100),XH2S1(100)

COMMON TBIN,FLBR,FLIC4

COMMON PRBOIL,TSAT,KBOIL,YCO2BX,YH2SBX,XIBMX,XCC2BX,XH2SBX

COMMON TBOIA,TBLCGH,RPD,TCCNC,PRCCAC,YCC2C(100),YH2SC(100),

1XCO2C(100),XH2SC(100),COND1(100),NCOND,GCOND(100)

COMMON RVERT,NHORIZ

COMMON V1(30),V2(30),P1(30),P2(30),TVAP(30),T1(31),X1(30)

COMMON X2(30),P11(30),P12(30),FL(30),FLCC2(30)

C CALCULATE BRINE DENSITY AND SALT CLARITY

N=NBOIL

K=N+1

DO 100 I=1,K

IF(T(I).LT.100.) RHGW=1.0

IF(T(I).GE.100.) RHGW=1.04-T(I)*4.E-04

RHGB=RHGW+G.GC73*WPB

SALTM=(WPB/585.)*RHGB

C HCO2W IS HENRY'S CONSTANT FOR CO₂ IN WATER

IF(T(I).LT.212.) HCO2W=-77.+24.4*T(I)

IF(T(I).GE.212.) HCO2W=1560.+16.7*T(I)

IF(T(I).GE.300.) HCO2W=6600.

IF(T(I).GE.390.) HCO2W=12200.-14.4*T(I)

IF(T(I).LT.212.) HH2SW=123.+6.87*T(I)

IF(T(I).GE.212.) HH2SW=921.+3.11*T(I)

IF(T(I).GE.302.) HH2SW=1390.+1.55*T(I)

IF(T(I).GE.392.) HH2SW=2435.-1.11*T(I)

IF(T(I).GE.482.) HH2SW=3400.-3.11*T(I)

C SOCO2 IS SALTING COEFFICIENT

C HCO2B IS HENRY'S CONSTANT FOR CO₂ IN BRINE

IF(T(I).LT.250.) SOCO2=0.078

IF(T(I).GE.250.) SOCO2=0.073

IF(T(I).GE.350.) SOCO2=0.088

IF(T(I).GE.450.) SOCO2=0.124

IF(T(I).GE.530.) SOCO2=0.168

SOH2S=0.10

PCO2B(I)=HCO2W*(10.**(SOCO2*SALTM))*14.7

100 HH2SB(I)=HH2SW*(10.**(SOH2S*SALTM))*14.7

RETURN

END

/ GAS / SIZE OF PROGRAM 0004AC HEXA

TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.
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0 (01 JUN 79)

SYSTEM/370 FORTRAN H EXTENDED (ENHANCED)

DATE 81.056/17

IS: AUTOCBL(DBLPAD)

EFFECT: NAME(MAIN) OPTIMIZE(3) LINECOUNT(59) SIZE(MAX) AUTOCBL(DBLPAD)
 SOURCE EBCDIC NOLIST NODECK OBJECT MAP ACFORMAT GCSTMT NOXREF NOALC NOANSF TER

SUBROUTINE CNGSER

COMMON RHOB,NB,RHOF,SIGMAF,VPIC4,HIC4,MOLCC2,FG,HH2S,HCO2,
 1 VPH2O,DAIC4,DACO2,DAH2S,PPCO2,CO2ATM,PRCO2,TRCO2,H2SATM,
 1 PRH2S,TRH2S,IC4BET,CG2BET,H2SBET,
 1 HH2SC4,HCO2C4,DCO2,DH2S,VISIC4,
 1 BEGH2S,BEGCG2,TH2SA,TGO2A,TCO2B,TH2SE
 COMMON T(100),WPE,HCG2E(100),HH2SE(100),XCG2E0,XH2SE0,NBOIL
 COMMON TBOIL(100),XISO(100),XCO2B(100),XH2SB(100),YCC2(100),YH2S
 1(100),XCO2I(100),XH2SI(100)
 COMMON TBIN,FLBR,FLIC4
 COMMON PRBOIL,TSAT,KBOIL,YCO2BX,YH2SBX,XIBMX,XCG2BX,XH2SBX
 COMMON TBOIA,TBLGTH,RPD,TCEND,PRCOND,YCC2C(100),YH2SC(100),
 1 XCO2C(100),XH2SC(100),CGNDL(100),NCGND,GCGND(100)
 COMMON NVERT,NHGRIZ
 COMMON V1(30),V2(30),P1(30),P2(30),TVAP(30),TI(31),X1(30)
 COMMON X2(30),P11(30),P12(30),FL(30),FLCG2(30)

N=NBEL

V2(1)=4.46

IF(KBOIL.EQ.1)V1(1)=YCO2(N+1)*V2(1)

IF(KBOIL.EQ.2)V1(1)=YCC2BX*V2(1)

FL(1)=1.0E-6

TVAP(1)=140.6

THALL=66.0

PRCOND=71.6

TI(0)=89.1

J=1

P1(1)=(V1(1)/(V1(1)+V2(1)))*PRCOND

P2(1)=PRCOND-P1(1)

TI(1)=89.2

5 K=1

7 HCG2I=(40.+C.35*TI(J))*14.7

VPIC4=26.356*EXP(0.0112*TI(J))

X1(J)=(PRCOND-VPIC4)/HCG2I

TMAX=89.C*ALOG(PRCOND/26.356)

IF(X1(J).LT.0.0)TI(J)=TMAX-0.02

IF(X1(J).LE.0.0)X1(J)=2.6E-5

C CALCULATE VAPOR HEAT TRANSFER COEFFICIENT HG

GVAPOR=(V1(J)*44.+V2(J)*58.)/0.00451

VISC4V=(0.0067+1.2E-5*TI(J))*2.42

REVAP=0.0758*GVAPOR/VISC4V

AJH=0.023/(REVAP*0.2)

CPVAP=0.357+C.0006*TI(J)

TKVAP=0.0082+0.000022*TI(J)

PRVAP=VISC4V*CPVAP/TKVAP

HG=AJH*GVAPOR*CPVAP/(PRVAP*0.667)

IF(HG.LT.5.0)HG=5.0

C CALCULATE MASS TRANSFER COEFFICIENTS AKG1 AND AKG2

CCO2=0.0107*(1+(TI(J)+460.)/590.)*1.5)

RHC4VAP=1.2C*PRCOND*590./(110.*(TI(J)+460.))

SCCO2=VISC4V/(RHC4VAP*CCO2)

AKG1=AJH*GVAPOR/(58.*SCCO2*0.667)

DISIS=0.2440*(TI(J)+460.)*VISC4V/PRCOND

O (01 JUN 79)

CND SER

SYSTEM/370 FORTRAN H EXTENDED (ENHANCED)

DATE 81.056/17

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SCIV=SCC02*DC02/DISTS
AKG2=AJ1*GVAPOR/(58.*SCIV**0.667)
HVI=EXP(5.86-0.00637*TI(J))
VISC4L=(0.115-0.0025*((TI(J)-32.)/1.8-50.))*2.42
IF(REVAP.LT.3.5E4)GC TC 11
GLIQ=FL(J)*58.C/0.00451
RELIC=GLIQ*0.0758/VISC4L
REBAR=(REVAP*VISC4V*((32.0/RHOVAP)**0.5)/VISC4L)+RELIC
PRLIQ=VISC4L*0.667/0.0552
ANU=0.05*(REBAR**0.8)*((PRLIQ**0.333)
HL=ANU*0.0552/0.0758
GO TO 12

```

11 CONTINUE

```

HFAC=HVI+0.375*0.667*(TI(J)-TWALL)
HL=0.555*((32.0*4.173E8*((32.0-RHOVAP)*1.68E-4*HFAC/(VISC4L*
1*(TI(J)-TWALL)*0.0758))**0.25)
IF(HL.LT.20.)HL=20.0

```

12 CONTINUE

```

UPSD=(1.0/HL)+2.24E-4+53.02E-4
HO=1.0/UPSD
Y1=P1(J)/PRCNG
YI1=HCO21*X1(J)/PRCNGD
Y2=1.0-Y1
YI2=1.0-YI1

```

C CALCULATE MOLAR FLUXES

```

L=1
FLUX1=0.0
FLUX2=0.1
FLUXT=0.1

```

C ACKERMAN FAC IGR = ACKFAC

201 ACKFAC=FLUXT*CPVAP*58.0/HG

40 EXFAC=ACKFAC/(1.-EXP(-ACKFAC))

```

FLUX2=HO*((TI(J)-TWALL)/((CPVAP*58.C*(TVAP(J)-TI(J)))/(1.0-EXP(
1-ACKFAC)))+HVI*58.0)
FLUX1=FLUX2*X1(J)
FLUXT=FLUX1+FLUX2

```

L=L+1

IF(L.LT.3)GC TC 201

41 TICH=(HG*EXFAC*TVAP(J)+HO*TWALL+AKG1*(Y1-YI1)*2E75.C+AKG2*(YI1-

YI1)*HVI*58.C)/(HG+HG*EXFAC)

K=K+1

IF(TICH.LT.TWALL)TICH=TWALL+0.5

IF(TICH.GT.TI(J-1))TICH=TI(J-1)

TI(J)=(TI(J)+TICH)/2.0

IF(K.GT.5)GC TC 15

GO TO 7

15 J=J+1

IF(J.GT.30)GC TC 20

TI(J)=TI(J-1)

V1(J)=V1(J-1)-FLUX1*1.429

IF(V1(J).LE.0.)V1(J)=1.0E-6

V2(J)=V2(J-1)-FLUX2*1.429

IF(V2(J).LE.0.)V2(J)=1.0E-6

FL(J)=FL(J-1)+FLUXT*1.429

TVAP(J)=TVAP(J-1)-EXFAC*HG*(TVAP(J-1)-TI(J-1))*1.429/(GVAPCR*

10.00451*CPVAP)

IF(TVAP(J).LT.TI(J))TVAP(J)=TI(J)+0.1

C (01 JUN 79)

CNDSER

SYSTEM/370 FORTRAN H EXTENDED (ENHANCED)

DATE 81.056/1

GO TO 5
20 CONTINUE
RETURN
END

/ CNDSER /

SIZE OF PROGRAM 000B26 HEXA

TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME		
SFA	P	I*4	0002F0	K	SF	I*4	0002F8	L	SF	I*4	0002FC		
CD	R*8	NR	FL	SF	CD	R*8	004C58	HG	SF	CD	R*8	000038	
SF	D	R*8	000310	NB	CP	I*4	NR	P1	SF	CC	R*8	0038D0	
SFA	CC	R*8	003BA0	V1	SF	CD	R*8	0036F0	V2	SF	CD	R*8	0037E0
CD	R*8	NR	Y1	SF	D	R*8	000318	Y2	S	C	R*8	000320	
SF	D	R*8	000330	DEXP	F	XFO*	R*8	000000	HVI	SF	D	R*8	000338
CD	R*8	NR	RPD	CD	R*8	NR		WFB	CC	R*8	NR		
S	D	R*8	000348	AKG1	SF	D	R*8	000350	AKG2	SF	C	R*8	000358
SF	CC	R*8	000000	DH2S	CD	R*8	NR	FLBR	CD	R*8	NR		
CD	R*8	NR	HFAC	SF	D	R*8	000368	HH2S	CD	R*8	NR		
CC	R*8	NR	RHOF	CD	R*8	NR		SCIV	SF	D	R*8	000370	
SF	D	R*8	000378	TMAX	SF	D	R*8	000380	TSAT	CC	R*8	NR	
SF	D	R*8	000388	XISO	CD	R*8	NR	YCO2	F	CD	R*8	001718	
CD	R*8	NR	CPVAP	SF	D	R*8	000390	DACC2	CC	R*8	NR		
CD	R*8	NR	CISIS	SF	D	R*8	000398	EXFAC	SF	D	R*8	0003A0	
CD	R*8	NR	FLUXT	SF	D	R*8	0003A8	FLUX1	SF	C	R*8	0003B0	
CD	R*8	NR	HCC2B	CD	R*8	NR		FCO21	SF	C	R*8	0003C0	
CP	I*4	0023C0	NBQIL	F	CP	I*4	000A90	ACOND	CF	I*4	NR		
CD	R*8	NR	PRCO2	CD	R*8	NR		PRH2S	CC	R*8	NR		
SF	D	R*8	0003D0	REBAR	SF	D	R*8	0003D8	REL IQ	SF	D	R*8	0003E0
SF	D	R*8	0003F0	TBDIA	CD	R*8	NR	TECIL	CC	R*8	NR		
CD	R*8	NR	TCG2B	CD	R*8	NR		TH2SA	CD	R*8	NR		
SF	D	R*8	0003F8	TRCO2	CD	R*8	NR	TRH2S	CC	R*8	NR		
CD	R*8	NR	VPIC4	SF	CD	R*8	000020	XCO2B	CD	R*8	NR		
CC	R*8	NR	XH2SB	CD	R*8	NR		XH2SC	CC	R*8	NR		
CD	R*8	NR	YCO2C	CC	R*8	NR		YH2SC	CD	R*8	NR		
SFA	D	R*8	000408	BEQCO2	CD	R*8	NR	BEQH2S	CD	R*8	NR		
CD	R*8	NR	CO2BOT	CD	R*8	NR		CVAPOR	SF	C	R*8	000418	
CD	R*8	NR	H2SATM	CD	R*8	NR		H2SBOT	CD	R*8	NR		
CP	I*4	NR	NHORI2	CP	I*4	NR		FRBCIL	CC	R*8	NR		
SF	D	R*8	000420	SIGMAF	CD	R*8	NR	TELGH	CD	R*8	NR		
SF	D	R*8	000430	VISIC4	CD	R*8	NR	XCC2BX	CC	R*8	NR		
CD	R*8	NR	XH2S80	CD	R*8	NR		YCO2BX	F	CD	R*8	0023C8	

***** COMMON INFORMATION *****

E OF COMMON BLOCK * * SIZE OF BLOCK 004238 HEXADECIMAL BYTES

NAME	TYPE	REL. ADDR.	VAR.	NAME	TYPE	REL. ADDR.	VAR.	NAME	TYPE	REL. ADDR.	VAR.
NR	R*8	000000	NR	NB	I*4	000008	NR	RHOF	R*8	000010	NR
IC4	R*8	000020		HIC4	R*8	000028	NR	MCLCC2	I*4	000030	NR
H2	R*8	000040	NR	HCO2	R*8	000048	NR	VPH2C	R*8	000050	NR
CO2	R*8	000060	NR	DAH2S	R*8	000068	NR	PPCC2	R*8	000070	NR
CC2	R*8	000080	NR	TRCO2	R*8	000088	NR	H2SATM	R*8	000090	NR
H2S	R*8	0000A0	NR	IC4BOT	I*4	0000A8	NR	CC2ECT	R*8	0000B0	NR
SC4	R*8	0000C0	NR	HCO2C4	R*8	0000C8	NR	DCO2	R*8	0000D0	

TITLE: AUTODBL(DBLPAD)

 EFFECT: NAME(MAIN) OPTIMIZE(3) LINECOUNT(59) SIZE(MAX) AUTODBL(DBLPAD)
 SOURCE EBCDIC NCLIST NODECK OBJECT MAP NOFORMAT GOSTMT NOXREF NCALC NOANSF TER

SUBROUTINE OUTPUT

```

      COMMON RHOE,NB,RHOF,SIGMAF,VPIC4,HIC4,MOLCO2,FG,HH2S,HCO2,
1  VPH2C,DAIC4,DACO2,DAH2S,PPCO2,CC2ATV,PRCC2,TRCC2,P2SATM,
1PRH2S,TRH2S,IC4BOT,CO2BOT,H2SBOT,
1 HH2SC4,HCO2C4,CCG2,CH2S,VISIC4,
1 BEQH2S,BEQCO2,TH2SA,TGGA,TGG2E,TH2SE
      COMMON T(100),WPB,HCO2B(100),HH2SB(100),XCO2BC,XH2SBC,NBOIL
      COMMON TBOIL(100),XISC(100),XCO2E(100),XH2SE(100),YCO2(100),YH2S
1(100),XCO2I(100),XH2SI(100)
      COMMON TBIN,FLER,FLIC4
      COMMON PRBCIL,TSAT,KBCIL,YCC2BX,YH2SBX,XIBMX,XCC2BX,XH2SBX
      COMMON TBOIA,TBLGTH,RPD,TCOND,PRCOND,YCO2C(100),YH2SC(100),
1XCC2C(100),XH2SC(100),CNDL(100),NCCNC,GCONC(100)
      COMMON NVERT,NHORIZ
      COMMON V1(30),V2(30),P1(30),P2(30),TVAP(30),TI(31),XI(30)
      COMMON X2(30),PI1(30),PI2(30),FL(30),FLCO2(30)
      N=NBOIL
      IF(KBOIL.EQ.2)GC TC 335
      WRITE(6,338)
338 FORMAT(1H0,40X,'BOILER TYPE---COUNTER FLOW')
      GC TC 335
335 WRITE(6,336)
336 FORMAT(1H0,40X,'BOILER TYPE---BACKMIX')
339 WRITE(6,300)WF8
300 FORMAT(1H0,'WEIGHT PERCENT SALT IN BRINE=',5X,F4.1)
      WRITE(6,310)XCC2BO
310 FORMAT(1H0,'MOLE FRACTION CO2 IN INLET BRINE=',5X,F10.6)
      WRITE(6,320)XH2SBO
320 FORMAT(1H0,'MOLE FRACTION H2S IN INLET BRINE=',5X,F10.6)
      WRITE(6,330)TBIN
330 FORMAT(1H0,'BRINE INLET TEMPERATURE(F) = ',5X,F8.1)
      WRITE(6,331)TSAT
331 FORMAT(1H0,'BOILER SATURATION TEMP(F) = ',5X,F8.1)
      WRITE(6,332)PRBCIL
332 FORMAT(1H0,'BOILER PRESSURE(Psia) = ',5X,F8.1)
      WRITE(6,333)FLBR
333 FORMAT(1H0,'BRINE FLOW RATE (LB/HR) = ',5X,F8.1)
      WRITE(6,334)FLIC4
334 FORMAT(1H0,'ISOBUTANE FLOW RATE (LB/HR) = ',5X,F8.1)
      WRITE(6,350)
350 FORMAT(1H0,'BRINE TEMP(F)      BRINE ISO      BRINE CO2      BRINE
1H2S      VAPOR CO2      VAPOR H2S      ISO CO2      ISC H2S')
      C XCO2I(N),XCO2I(N+1),XH2SI(N),XH2SI(N+1) DO NOT EXIST-NO LIQUID PHASE
      XCO2I(N)=99.
      XCC2I(N+1)=99.
      XH2SI(N)=99.
      XH2SI(N+1)=99.
      IF(KBOIL.EQ.2)GC TC 340
      K=N+1
      DO 360 I=1,K
      WRITE(6,370) TBOIL(I),XISC(I),XCC2E(I),XH2SE(I),YCO2(I),YH2S(I),
1XCO2I(I),XH2SI(I)

```

```

370 FORMAT(1H0,3X,F6.1,10X,F8.6,6X,F8.6,6X,F8.6,6X,F8.6,6X,F8.6,6X,
1F8.6,6X,F8.6)

```

```

360 CONTINUE

```

```

    GC TC 361

```

```

340 WRITE(6,337)TBOIL(1),X1BMX,XCG2BX,XH2SBX,YCC2BX,YH2SBX

```

```

337 FORMAT(1H0,3X,F6.1,10X,F8.6,6X,F8.6,6X,F8.6,6X,F8.6,6X,F8.6)

```

```

361 CONTINUE

```

```

    WRITE(6,400)

```

```

400 FORMAT(1H0,20X,'500KW CONDENSER (ONE TUBE, 30 SEGMENTS)')

```

```

    WRITE(6,21)

```

```

21 FORMAT(1H0,'IC4 VAPOR RATE',3X,'CO2 VAPOR RATE',3X,'CCND RATE',
13X,'VAFER TEMP',3X,'INTFACE TEMP')

```

```

    WRITE(6,29)

```

```

29 FORMAT(1H0,4X,'LB/HR',12X,'LB/HR',10X,'LB/HR',8X,'DEG F',4X,'
1DEG F')

```

```

    DO 23 J=1,30

```

```

      VCG2=V1(J)*44.0

```

```

      VISG=V2(J)*58.0

```

```

      COND=FL(J)*58.0

```

```

      WRITE(6,22)VISC,VCO2,COND,TVAP(J),TI(J)

```

```

22 FORMAT(1H0,2X,F9.2,7X,F9.4,6X,F9.3,5X,F9.3,5X,F9.3)

```

```

23 CONTINUE

```

```

    RETURN

```

```

    END

```

/ OUTPUT / SIZE OF PROGRAM 000712 HEXAD

TAG	TYPE	ADD.	NAME	TAG	TYPE	ADD.	NAME	TAG	TYPE	ACC.
	I*4	0003C4	J SF		I*4	0003C8	K SF		I*4	0003CC
CD	R*8	NR	FL F	CD	R*8	004058	HC	CC	R*8	NR
CD	R*8	NR	P2	CD	R*8	NR	TI F	CD	R*8	003BA0
CD	R*8	0037E0	X1	CD	R*8	NR	X2	CC	R*8	NR
CC	R*8	NR	RPD	CD	R*8	NR	WPB F	CD	R*8	000438
CC	R*8	NR	DH2S	CD	R*8	NR	FLBR F	CD	R*8	0023A0
CD	R*8	NR	HIC4	CC	R*8	NR	RHCB	CC	R*8	NR
CC	R*8	002398	TSAT F	CD	R*8	0023B8	TVAP F	CD	R*8	003AB0
D	R*8	0003E8	XISO F	CD	R*8	000DB8	YCO2 F	CD	R*8	001718
CD	R*8	NR	CACO2	CD	R*8	NR	CAH2S	CD	R*8	NR
CD	R*8	NR	FLIC4 F	CD	R*8	0023A8	GCCND	CC	R*8	NR
CD	R*8	NR	KBCIL	CP	I*4	0023C0	NBOIL F	CP	I*4	000A90
CP	I*4	NR	PPCO2	CD	R*8	NR	FRCC2	CC	R*8	NR
CD	R*8	NR	TBCIL F	CD	R*8	000A98	TCOND	CC	R*8	NR
CD	R*8	NR	TH2SA	CD	R*8	NR	TH2SB	CD	R*8	NR
CD	R*8	NR	VPH20	CD	R*8	NR	VPIC4	CC	R*8	NR
CC	R*8	NR	XCO2I SF	CD	R*8	001058	XH2SB F	CD	R*8	0013F8
CD	R*8	002C78	X1BMX F	CD	R*8	0023D8	YCC2C	CC	R*8	NR
CD	R*8	NR	BEQH2S	CD	R*8	NR	CO2ATM	CC	R*8	NR
CD	R*8	NR	HH2SC4	CD	R*8	NR	H2SATM	CC	R*8	NR
XF	I*4	000000	IC4BCT	CP	I*4	NR	MOLCO2	CP	I*4	NR
E	R*8	0003F0	PRBOIL F	CD	R*8	0023B0	FRCCND	CC	R*8	NR
CD	R*8	NR	VISIC4	CD	R*8	NR	XCC2BX F	CC	R*8	0023E0
CC	R*8	0023E8	XH2SB0 F	CD	R*8	00CA8E	YCO2BX F	CD	R*8	0023C8

***** COMMON INFORMATION *****

BOILER TYPE---BACKMIX

WEIGHT PERCENT SALT IN BRINE= 0.2

MOLE FRACTION CO2 IN INLET BRINE= 0.000350

MOLE FRACTION H2S IN INLET BRINE= 0.000001

BRINE INLET TEMPERATURE(F) 340.0

BOILER SATURATION TEMP(F) = 250.0

BOILER PRESSURE(PSTIA) = 467.3

BRINE FLOW RATE (LB/HR) = 97200.0

ISOBUTANE FLOW RATE (LB/HR) = 99400.0

BRINE TEMP(F)	BRINE ISC	BRINE CO2	BRINE H2S	VAPOR CO2
263.7	0.000075	0.000035	0.000000	0.010026

500KW CONDENSER-(ONE TUBE,30 SEGMENTS)

IC4 VAPOR RATE	CO2 VAPOR RATE	COND RATE	VAPOR TEMP	INTFACE TEMP
LB/HR	LB/HR	LB/HR	DEG F	DEG F
258.68	1.9675	0.000	140.600	88.427
254.14	1.9654	4.547	101.435	84.456
244.42	1.9388	14.293	88.515	82.893
231.80	1.8926	26.981	84.168	82.264
218.43	1.8388	40.420	82.673	81.941
205.10	1.7825	53.826	82.090	81.710
192.03	1.7257	66.968	81.783	81.501
179.30	1.6688	79.772	81.552	81.292
166.94	1.6120	92.211	81.336	81.076
154.55	1.5554	104.272	81.116	80.849
143.36	1.4992	115.941	80.887	80.612
132.16	1.4434	127.209	80.647	80.361
121.38	1.3881	138.067	80.393	80.097
111.01	1.3333	148.504	80.125	79.818
101.06	1.2793	158.510	79.842	79.522
91.58	1.2259	168.076	79.541	79.209
82.53	1.1735	177.197	79.222	78.875
73.93	1.1221	185.861	78.881	78.519
65.80	1.0717	194.061	78.619	78.146
58.14	1.0226	201.785	78.246	77.739

CONTINUED

IC4 VAPOR RATE	CO2 VAPOR RATE	CCND RATE	VAPOR TEMP	INTFACE TEMP
LB/HR	LB/HR	LB/HR	DEG F	DEG F
50.96	0.9749	209.033	77.835	77.255
44.25	0.9287	215.800	77.399	76.824
38.03	0.8841	222.080	76.524	76.310
32.25	0.8413	227.872	76.410	74.343
26.53	0.7918	233.704	74.443	73.414
21.30	0.7441	238.988	73.514	72.521
16.67	0.6994	243.678	72.621	71.611
12.65	0.6586	247.754	71.711	70.700
9.24	0.6221	251.213	70.800	69.819
6.43	0.5907	254.063	69.919	68.987

PREHEATER TEMP AND CONCENTRATION PROFILES

ALL CONC IN MOLE FRACTIONS

BRINE TEMP (F)	ISO TEMP (F)	ISO IN BRINE	CO2 IN BRINE	H2S IN BRINE	CO2 IN ISO
251.01	250.70	0.000077	0.000060	0.000000	0.009280
250.25	249.90	0.000083	0.000093	0.000000	0.009487
249.40	249.02	0.000087	0.000120	0.000000	0.009672
248.47	248.05	0.000089	0.000141	0.000000	0.009836
247.44	246.98	0.000090	0.000159	0.000000	0.009985
246.36	245.80	0.000091	0.000174	0.000000	0.010119
245.05	244.49	0.000090	0.000187	0.000000	0.010243
243.67	243.05	0.000090	0.000197	0.000000	0.010353
242.14	241.47	0.000089	0.000207	0.000000	0.010454
240.46	239.72	0.000089	0.000215	0.000000	0.010544
238.61	237.79	0.000088	0.000223	0.000000	0.010624
236.57	235.66	0.000087	0.000229	0.000000	0.010692
234.32	233.32	0.000085	0.000235	0.000000	0.010752
231.63	230.73	0.000084	0.000241	0.000000	0.010800
229.09	227.88	0.000083	0.000247	0.000000	0.010836
226.07	224.73	0.000082	0.000252	0.000000	0.010861
222.74	221.26	0.000080	0.000257	0.000000	0.010875
219.07	217.44	0.000079	0.000262	0.000000	0.010877
215.02	213.22	0.000077	0.000268	0.000000	0.010867
210.55	208.57	0.000075	0.000273	0.000000	0.010846
205.63	203.44	0.000074	0.000279	0.000000	0.010814
200.19	197.78	0.000072	0.000285	0.000000	0.010772
194.20	191.54	0.000070	0.000290	0.000000	0.010718

BRINE TEMP(F)	ISO TEMP(F)	ISO IN BRINE	CO2 IN BRINE	H2S IN BRINE	CO2 IN ISO
187.60	184.66	0.000068	0.000297	0.000000	0.010658
180.31	177.08	0.000067	0.000303	0.000000	0.010590
172.28	168.71	0.000065	0.000310	0.000000	0.010518
163.42	159.48	0.000063	0.000317	0.000000	0.010444
153.65	149.31	0.000061	0.000325	0.000000	0.010374
130.90	126.66	0.000058	0.000341	0.000000	0.010076